Synthesis and Physical Properties of Al-ZnO Thin Film by Thermal Evaporation

การสังเคราะห์และสมบัติเชิงฟิสิกส์ของฟิล์มบาง Al-ZnO โดยวิธีไอระเหยความร้อน

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ABSTRACT

Al-doped ZnO thin films were synthesized by thermal evaporation. Zinc acetate and aluminum chloride were used as precursors. The synthesis process was performed in a vacuum system equipped with a diffusion pump and rotary pump at the pressure of 50 mtorr. The films were annealed in atmospheric pressure at 450 °C for 30 min and characterized by means of X-ray diffraction (XRD), UV-vis spectrometry, and four-point probe measurement. The films show hexagonal structure and have resistance of 50 ohm/square. The adhesive of the films were good and the transmittance of the films was about 80%.

บทคัดย่อ

ฟิล์มบาง Al-ZnO ถูกสังเคราะห์โดยวิธีไอระเหยความร้อน Zinc acetate และ aluminum chloride ถูกใช้เป็นสารตั้งต้น กระบวนการสังเคราะห์ฟิล์มบางถูกทำในระบบสุญญากาศที่ประกอบไปด้วยปั๊มแพร่ไอและโรตารี่ปั๊มที่ความดัน 50 มิลลิทอรร์ ฟิล์มถูกอบร้อนในความดันบรรยากาศที่อุณหภูมิ 450 °C เป็นเวลา 30 นาที และได้นำไปศึกษาสมบัติบ่งชี้ด้วยเทคนิคการเลี้ยวเบนรังสีเอกซ์ การวัดการทะลุผ่านของแสงและวัดความต้านทานด้วยเทคนิคสี่ขั้ว ฟิล์มมีโครงสร้างเป็นเฮกซะโกนอลและมีความต้านทานประมาณ 50 โอห์มต่อตารางพื้นที่ การยึดติดแน่นของฟิล์มอยู่ในเกณฑ์ดีและมีการส่งผ่านของแสงประมาณร้อยละ 80

Key Words: Zinc Oxide (ZnO) Thin Film, Thermal Evaporation, TCO (Transparent conducting oxide)

คำสำคัญ: ฟิล์มบางซิงค์ออกไซด์ ไอระเหยความร้อน ออกไซด์ตัวนำโปร่งแสง

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Introduction

Zinc oxide (ZnO) is a wide band gap semiconductor and has attracted much attention as transparent conducting oxide (TCO) electrodes in solar cells, gas sensor and more recently as transistors [1]. The presence of a large exciton binding energy makes ZnO a promising material for optoelectronic devices in UV region.

Several techniques were employed to synthesize previous ZnO namely, sputtering [2], spray pyrolysis [3], sol–gel dip coating [4] and evaporation [5]. In thermal evaporation method, ZnO thin films were initially deposited and then annealed in air or oxygen atmosphere. The deposition of these was carried out by thermal evaporation process from Zn powder or ZnO powder in a furnace [6]. The present paper is devoted to the preparation and examine the influence of ZnO thin films by vacuum thermal evaporation, thermal annealing in air on the structure, the electrical and optical properties.

Materials and methods

Zinc acetate and aluminum chloride were used as starting materials and was preheated in air at 250 °C. The preheated precursors were ground and placed in a tungsten boat. The substrates were glass slide and ultrasonically cleaned and placed above the source at a distance of 5 cm. The vacuum chamber was stainless steel equipped with diffusion and rotary pumps. The base pressure was about 50 mtorr. The current was supplied by 200A dc power supply of about 100 Ampere. The chemical reaction for the films is

$$Zn(CH_3COO)_2 \longrightarrow ZnO + CO_2 + CH_3COCH_3$$

The films were annealed in atmospheric pressure at 450-500 °C for 30 min. The apparatus set up is shown in Figure 1. The structure, properties, and adhesive of the films were examined. Phillip X'pert X-ray diffractometer with CuKα radiation at 1.54 Å was used to analyze the crystal structure. Optical transmittance measurements were performed by Perkin UV-visible spectrometer. Sheet resistance was measured by four-point probe method. The adhesive strength of the films was examined by sticking and peeling off using 3M tapes.

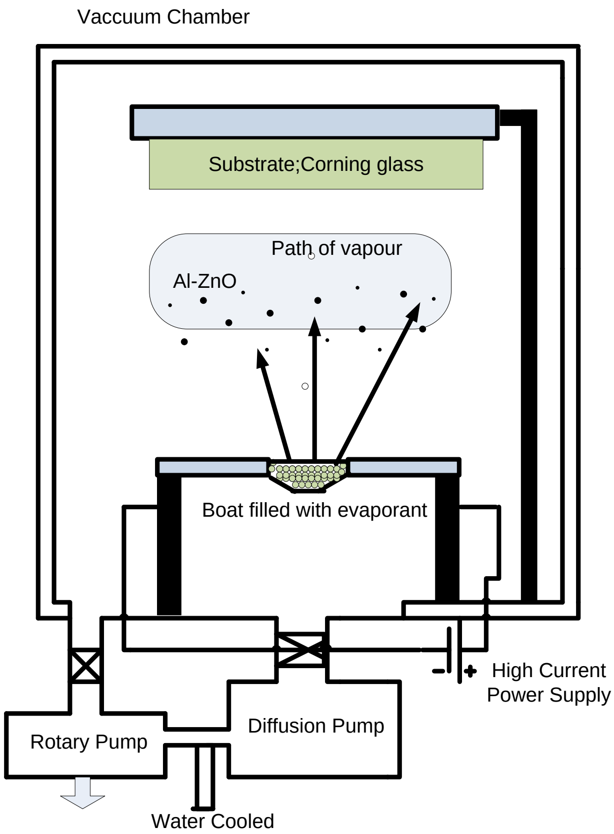

Figure 1 Schematic diagram of the vacuum thermal evaporation system for Al-ZnO thin film deposition

Results and Discussion

The Al-doped thin films as deposited were amorphous. The annealed films were crystalline structure. The XRD pattern of the film is shown in Figure 2.

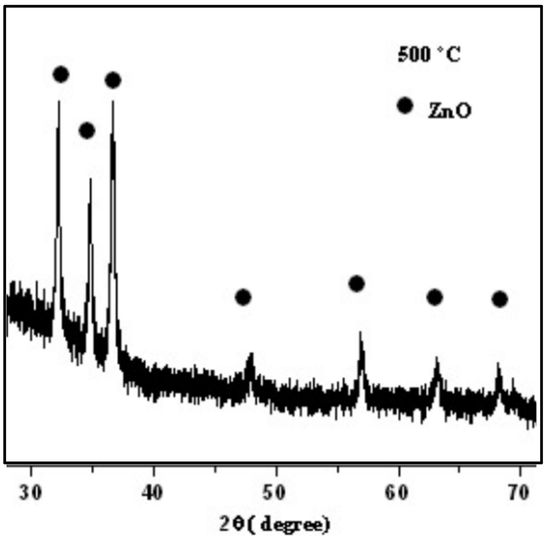

Figure 2 XRD pattern of annealed ZnO thin film

The structure of the films is Wurtzite structure with hexagonal in P63mc pace group lattice parameters, a = b = 3.24 Å and c = 5.20 Å. The XRD patterns of films with different amount of Al – doped ZnO are similar with ZnO films (figure is not shown). XRD data analysis reveals that

Optical transmittance spectra of Al-ZnO with different annealing temperatures are shown in Fig.3. All of the films provide good transparency with a transmittance coefficient above 80. The films annealed at 450 °C have the best transparency. The optical bangap (E_g) can be obtained by using Tauc's plot [7],

$$(\alpha h\upsilon)^{1/2} = A(h\upsilon\text{-}E_g)$$

where α is the absorption coefficient (cm^{-1}), A is a constant which is independent of photon energy, and $h\upsilon$ (eV) is the energy of excitation. The calculation of the bandgap can be performed by plotting $(\alpha h\upsilon)^{1/2}$ versus $h\upsilon$ and extrapolating of the absorption edge to zero as shown in Fig.4. The values of the bandgap are from 3.35 to 3.74 eV.

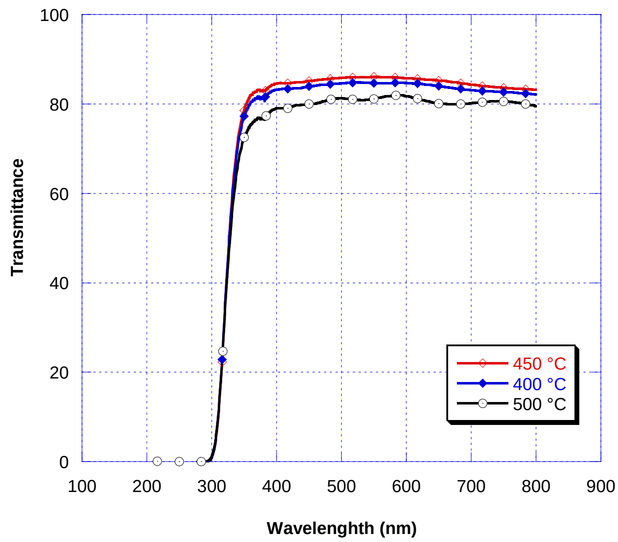

Figure 3 Optical transmittance spectra of Al-ZnO with different annealing temperatures

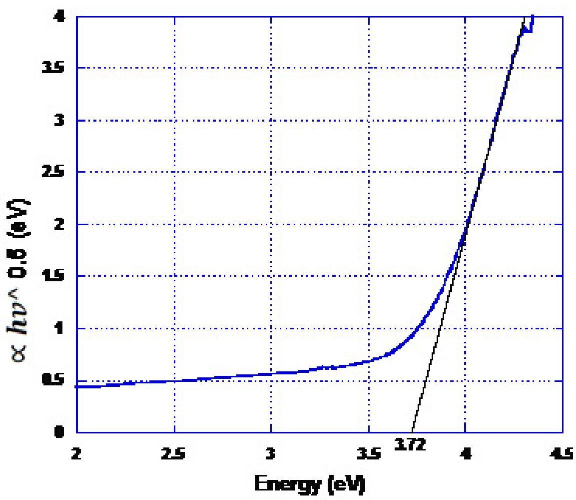

Figure 4 The Tauc's plot of of variation of $(\alpha h\upsilon)^{1/2}$ and energy for ZnO thin films annealed at 500°C

The sheet resistances of the films 4% Al – doped films annealed at 400, 450, and 500 °C are 65, 50, and 70 Ω/sq. respectively. The adhesive strength test indicates that the films have good stick with the substrates.

Conclusions

We have synthesized Al-doped ZnO thin films by vacuum thermal evaporation method. The films become crystalline after annealed in air. The optimal annealing temperature is 450 °C. The films have transmittance about 80% with optical bandgap between 3.35 and 3.74 eV. The lowest sheet resistance is 50 Ω/sq for 4% Al-doped ZnO thin films annealed at 450 °C. The films also show good adhesive strength. The films show good physical properties for the use as transparent conducting oxide.

Acknowledgements

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